Journal of Professional Nursing 62 (2026) 155–166

Contents lists available at ScienceDirect

Journal of Professional Nursing

journal homepage: www.elsevier.com/locate/jpnu

Impact of simulation-based education on pediatric and medical-surgical nursing education: A meta-analysis

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A R T I C L E I N F O

Keywords:
High-fidelity simulation
Low-fidelity simulation
Psychomotor skills
Cognitive outcomes
Self-efficacy

A B S T R A C T

Purpose: In this meta-analysis, researchers examined the impact of high-fidelity simulation (HFS) and low-fidelity simulation (LFS) on the development of psychomotor skills, cognitive outcomes, and self-efficacy among nursing students, emphasizing pediatric and medical-surgical nursing.
Methods: In total, 18 studies involving over 4000 nursing students were systematically reviewed. Studies that focused on simulation-based education were included. The effect size for each simulation type was calculated for psychomotor skills, cognitive outcomes, and self-efficacy using the standardized mean difference.
Results: Compared with LFS, which exhibited a moderate effect size of 0.56, HFS significantly improved clinical skills, cognitive outcomes, and self-efficacy, with a pooled effect size of 0.86. Pediatric nursing students demonstrated the highest improvement (effect size, 0.82), followed by medical-surgical nursing students (effect size, 0.65), thereby indicating that HFS simulation was more effective for pediatric and medical-surgical specialties.
Conclusion: HFS and LFS instructional techniques can significantly improve the clinical decision-making, skill, and confidence levels of students. These findings provide insights into the incorporation of HFS in the nursing education curriculum, especially in pediatric and medical-surgical nursing, where clinical judgment is vital.

Introduction

Nursing students use simulations across all educational levels to enhance their clinical skills. Following advancements in healthcare systems, nursing programs are embracing new teaching methodologies that enhance the students' clinical skills. Notably, simulation provides an opportunity for nursing students to practice several important clinical skills and various decision-making processes in a safe setting with no immediate risk to patients. Several simulation modalities, including high-fidelity simulation (HFS) and low-fidelity simulation (LFS), have been developed for enhancing nursing students' skill acquisition and practice (INACSL Standards Committee et al., 2021). HFS is an advanced simulation using computer-driven mannequins that mimic complex human physiology (e.g., heart rate, breathing) that offers realistic clinical scenarios to enhance critical thinking, clinical judgment, and teamwork. Meanwhile, LFS is a type of simulation that utilizes basic mannequins (e.g., task trainers, static models) or simple role-play with minimal technological integration.

Studies have reported improved learning outcomes with simulations; however, the efficiency of skill development especially clinical decision-making varies. The inclusion of diverse nursing specialties further complicates comparisons. HFS offers greater realism and immersion, whereas LFS is more cost-effective and easier to implement. As such, it remains unclear which model more effectively fosters clinical competence, decision-making, and self-efficacy across nursing specialties, such as pediatric and medical-surgical nursing. To address this gap, researchers conducted a meta-analysis to evaluate the impact of simulation fidelity on nursing students' skill acquisition, practice, and learning outcomes. Researchers also examined whether simulation-based strategies produce different effects across specialties like pediatric and

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https://doi.org/10.1016/j.profnurs.2025.11.010
Received 4 May 2025; Received in revised form 20 November 2025; Accepted 20 November 2025
Available online 23 November 2025

medical-surgical nursing, focusing on nursing students' psychomotor skills, cognitive outcomes, and self-efficacy.

Literature review

Historical context of simulation in nursing education

Simulation is integral to nursing curricula, complementing clinical placements for building technical skills and emotional competence. In nursing education, simulation has developed considerably since the 1960s, evolving from basic task trainers to sophisticated, technology-integrated tools. Early simulators enabled the practice of basic skills, such as blood pressure measurement and injections, but lacked realism and limited in critical decision-making practice (Gaba, 2004; Weersink et al., 2019; Ziv et al., 2003). These hindrances contributed to the development of HFS in the 1980s, a significant milestone in educational innovation (Elendu et al., 2024; Park & Yu, 2018). HFS uses computer-driven mannequins that simulate physiological responses, allowing safe practice of clinical scenarios, such as trauma care and resuscitation (Couperus et al., 2020; Herur-Raman et al., 2021; Pai, 2018). Meanwhile, virtual reality (VR) enhanced experiential learning, particularly communication and patient interaction (Sarmasoglu et al., 2016; Ziv et al., 2003). Present strategies integrate HFS and VR within blended learning models to foster reflection, critical thinking, and clinical confidence (Kiernan & Olsen, 2020; Penalo & Store, 2022; Wiskin et al., 2018).

Types of simulation in nursing education

Simulation modalities include HFS, LFS, virtual reality (VR), and augmented reality (AR) (Chavez, 2020; Glauberman et al., 2023). As shown in Fig. 1, traditional simulation modalities (LFS and HFS, totaling 70 %) still dominate the body of research being reviewed. However, the combined VR and AR approaches (30 % total) represent a substantial, and likely increasing, segment of the literature, reflecting the integration of advanced technology into simulation research. The use of each modality is determined by the specific advantages and limitations it possesses, which often depend on institutional financial resources and the high demand for and limited availability of traditional clinical placements.

High-fidelity simulation

HFS uses advanced mannequins that mimic respiration, vital signs, and drug responses, supporting training for scenarios such as cardiac arrest and trauma (Glauberman et al., 2023; Pai, 2018; Palmer et al., 2014). HFS improves clinical skills and decision-making by immersing students in realistic, time-sensitive situations (Alconero-Camarero et al., 2021; Guerrero et al., 2022). Debriefing sessions promote reflective practice, a means of thinking about what you did after training to learn from your experience and get better next time (de Oliveira et al., 2018; Hilleren et al., 2022) and clinical reasoning, thereby underpinning learning (Ann Kirkham, 2018; Tseng & Hill, 2020). However, high costs and resource demands limit accessibility in certain settings (Alinier, 2010; Cook et al., 2011). The high costs associated with maintaining HFS including infrastructure, consumables, and the need for dedicated, highly trained operational staff present a significant barrier. This resource strain often leads to inequity in educational access, resulting in a stark disparity in simulation quality and usage between well-funded academic medical centers and smaller community programs or low-resource global settings. The rapid pace of technological obsolescence also necessitates frequent, costly upgrades, making long-term sustainability a major consideration for program administrators.

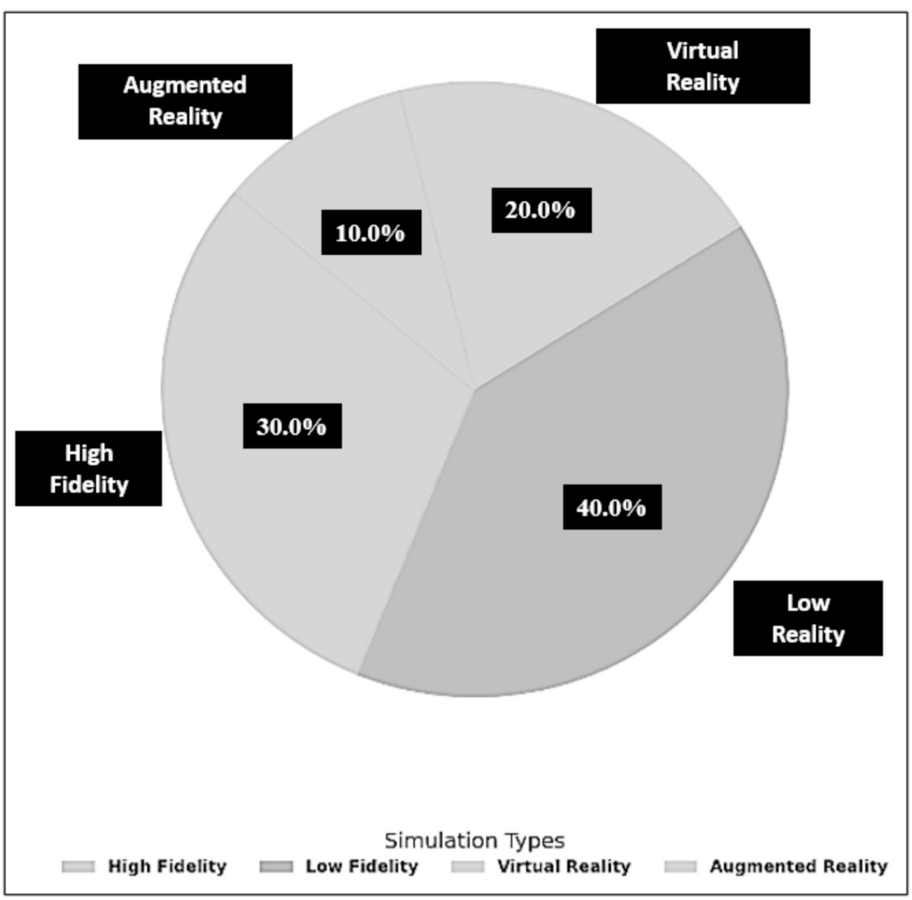

Fig. 1. Simulation types in nursing education.

Low-fidelity simulation

LFS involves the use of simple mannequins, a basic, non-electronic model of the human body or body part, for practicing fundamental nursing skills for teaching fundamental nursing procedures such as physical assessments, injections, and wound care (Meurling et al., 2014; Thomas et al., 2023). LFS effectively builds foundational skills and is widely adopted due to its affordability and ease of implementation (Alinier, 2010; Kiernan & Olsen, 2020; Lasater, 2007); although it is less realistic than HFS. While less effective for promoting higher-order thinking (Kim et al., 2016; Carey & Rossler, 2023), combining LFS with lectures and clinical experiences enhances competence and confidence (Alinier, 2010).

Virtual reality and augmented reality

VR and AR are emerging technologies in nursing education, offering interactive learning without the need for physical mannequins. VR allows students to engage in diverse clinical scenarios from chronic care to emergencies while developing both technical and soft skills such as communication and empathy (Biyik Bayram & Çalışkan, 2022; Quail et al., 2016). Meanwhile, AR enhances real-time clinical performance by overlaying digital guidance during procedures, such as physical examination and medication administration (Liu et al., 2025; Yaseen et al., 2025). Despite their educational benefits, the use of VR and AR faces challenges due to high costs, technological requirements, and limited curricular integration (AlGerafi et al., 2023; Lasater, 2007). The degree of curricular integration acts as a critical moderator of simulation effectiveness; poorly integrated simulation becomes a standalone event that fails to translate into lasting clinical judgment gains. Moreover, the lack of complete sensory immersion, such as the real-time responses, physical interactions, and emotional cues present in actual clinical settings, may limit the effectiveness of simulations in fully developing skill-based competencies. Nonetheless, several studies have reported their potential to improve knowledge retention, practical skills, and learner satisfaction (Cho & Kim, 2023; Xu et al., 2021).

Outcomes of simulation-based nursing education

Using LFS, HFS, AR, and VR simulations has positively influenced nursing education, enhancing training in clinical skills, knowledge, professional behavior, and learner satisfaction. By replicating complex, real-world scenarios, simulation-based learning allows students to apply theoretical concepts and receive feedback, effectively bridging the gap between classroom instruction and safe clinical practice.

Core clinical skills

Core clinical skills in nursing simulation refer to the fundamental hands-on and decision-making abilities, such as vital signs monitoring, patient assessment, medication administration, and emergency response (Hilleren et al., 2022). Notably, the use of LFS, HFS, AR, and VR simulations improves the clinical skills of nursing students. Students receiving LFS, HFS, AR, and VR simulation-enhanced training perform better in evaluations of medication administration, physical examination, and medical emergency management (Alharbi & Alharbi, 2022; Kiernan & Olsen, 2020). Learning using these simulation modalities allows students to enhance their skills without the risk of patient harm and better integrates theoretical knowledge with practical experience (Lasater, 2007). The impact of the different types of simulation-based nursing on core clinical skills is depicted in Fig. 2.

LFS, HFS, AR, and VR simulation trainings significantly enhance technical skill development, especially when coupled with structured debriefings and reflective practice. HFS yields greater skill acquisition and clinical performance than LFS does (Ann Kirkham, 2018; Tseng & Hill, 2020).

Knowledge acquisition and retention

Simulations improve the quality of learning processes by enhancing knowledge acquisition and retention. It bridges the gap between clinical work and classroom learning (Mattout et al., 2023) through hands-on experience that strengthens understanding, boosts memory retention, and helps bridge the gap between classroom instruction and actual clinical practice. Students who participate in simulation-based training show improved retention of psychomotor skills, including tasks such as inserting intravenous lines and performing cardiopulmonary resuscitation; cognitive outcomes such as clinical decision-making, interpreting lab results, and prioritizing care; and self-efficacy that reflects a student's confidence in managing emergencies and effectively communicating with patients and the healthcare team (Elendu et al., 2024; Mulyadi et al., 2021). Simulations enable nursing students to actively apply and practice specific skills such as medication administration, patient assessment, and emergency interventions in a controlled, realistic environment, thereby enhancing retention of theoretical knowledge and improving their ability to perform complex clinical tasks confidently and accurately. These clinical scenarios that replicate real-world situations allow students to reassess their knowledge and deepen their

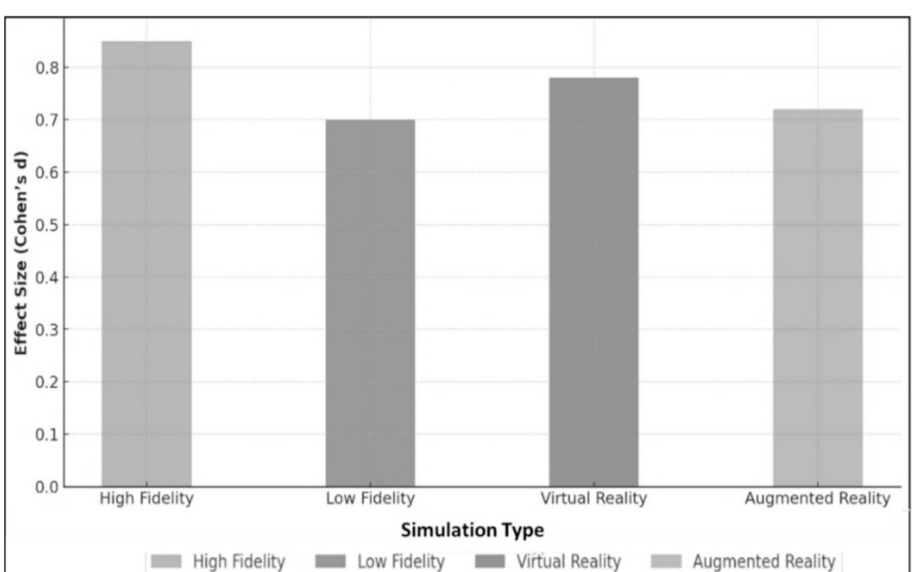

Fig. 2. Impact of simulation types on clinical skills improvement.

understanding for effective long-term retention (Ruth, 2023).

Hands-on methods, such as simulation activities, yield better retention than lectures or reading, as learners are more active and engaged (Liu et al., 2025). This model promotes deeper processing, enabling learners to not only recall information but also understand mechanistic principles and apply acquired knowledge (Demirci, 2017; Miskiah et al., 2020). Additionally, educators can provide immediate feedback, which helps correct misconceptions, reinforces accurate information, and improves retention (McDavid, 2013). Furthermore, simulation activities followed by reflective debriefing, a guided discussion after a training session where participants review what happened, think about their actions, and learn how to improve for the future, encourage deeper assimilation of information by fostering the discussion of learned concepts and their application (de Oliveira et al., 2018).

Psychomotor skills

Nursing simulation plays a crucial role in developing psychomotor skills, which involve the hands-on abilities required for patient care. Through realistic practice with mannequins or task trainers, nursing students refine essential techniques such as administering injections, inserting intravenous lines, performing catheterization, and managing airway devices. These simulations provide a safe environment where learners can repeatedly practice procedures, improving their hand-eye coordination, precision, and confidence. Deliberate practice combined with simulation significantly improves both the acquisition and retention of psychomotor skill competency (Johnson et al., 2020). Furthermore, by creating a controlled setting for mastery and reflection, simulation also advances crucial cognitive skills like flexible and reflective thinking (Tseng & Hill, 2020), ultimately enhancing overall performance and patient outcomes in real clinical situations.

Cognitive outcomes

The core cognitive outcomes in nursing education involve the mastery of critical thinking and clinical decision-making skills. These essential intellectual abilities are indispensable for the nurse to perform effective patient assessment, engage in rigorous problem-solving, and ultimately deliver safe, evidence-based care, which is vital for achieving the comprehensive competency necessary to reduce skill-based errors (Johnson et al., 2020).

Today, simulation technology helps students engage actively in clinical reasoning by recalling and applying previously acquired knowledge (Cecílio-Fernandes et al., 2018). Simulation promotes critical thinking and clinical decision-making (Wong et al., 2020), which are fundamental for practicing nurses. Additionally, it supports clinical assessment, triage, and decision-making processes to a greater extent than traditional methods (Zarifsanaiey et al., 2016). Simulations also significantly enhance learners' ability to respond effectively to challenging, high-stakes situations that require quick decision-making, thereby improving their confidence in their clinical reasoning and judgment skills (Bambini et al., 2009; Sterner et al., 2023).

Simulation improves clinical decision-making by enabling students to manage complex patient cases and prioritize nursing tasks efficiently (Alharbi & Alharbi, 2022). The repeated practice of simulation across varied contexts can help students gain a deeper understanding of the consequences of their choices and encourage them to refine their reasoning. This environment improves the ability to make decisions under stress, which is critical in clinical practice (Farina et al., 2019; Hoa & Tuan, 2021; Jenness, 1988). Furthermore, participation in multidisciplinary group simulations fosters collaboration and promotes critical thinking by encouraging diverse perspectives and problem-solving approaches (Mauriz et al., 2021).

Debriefing after every simulation scenario is crucial for developing critical thinking. During this reflection phase, students self-assess their performance, identify weaknesses, and build on their strengths. This repeated process internalizes clinical reasoning, thus preparing them for real-world practice, where clinical decisions directly affect patient health (Cecílio-Fernandes et al., 2018).

Self-efficacy, satisfaction, and confidence

One of the key benefits of simulation-based education is its impact on student satisfaction and self-esteem (Alharbi & Alharbi, 2022). Participation in simulation exercises increases students' perceived competence in meeting clinical demands (Sarmasoglu et al., 2016; Souza et al., 2020). Students who engage in simulation-based learning take more ownership of their educational processes and clinical placements (Guerrero et al., 2022; Khalil et al., 2023; Souza et al., 2020). This is largely attributed to opportunities for practicing "real-life" scenarios in a risk-free environment, where mistakes are viewed as learning opportunities rather than failures (Elendu et al., 2024; Kaliyangile, 2020). In these simulation settings, intellectual and emotional development occur simultaneously, significantly enhancing students' perceptions of their abilities and skills (Alrashidi et al., 2023).

Simulation-based education also provides feedback, allowing learners to identify strengths and weaknesses. This performance-reflection feedback loop promotes skill refinement and fosters a stronger sense of achievement (Altinbas et al., 2025). Through hands-on activities, students gain confidence and reassurance in their clinical decision-making and judgment skills (Serah et al., 2020), preparing them to face real-world nursing challenges more effectively.

Furthermore, simulations help students develop essential patient care skills, such as communication, teamwork, and leadership (Shin et al., 2017). Participation in multidisciplinary simulations increases collaboration and boosts students' self-efficacy in team-based healthcare delivery (Guerrero et al., 2022; Souza et al., 2020). The active engagement and immediate feedback inherent in simulation further strengthen self-esteem and confidence among nursing students (Alrashidi et al., 2023).

Challenges in implementing simulation

Despite its benefits, simulation-based learning is costly, especially HFS, which requires advanced manikins, software, and dedicated labs. In contrast, LFS uses simpler tools and is more affordable. HFS also demands ongoing maintenance, updates, and faculty training, making it less accessible for institutions with limited resources.

Many nursing programs lack funding for HFS and necessary supplies (Sivagami et al., 2025). Faculty members require advanced training for performing simulations and debriefings effectively, warranting considerable planning to ensure realistic and clinically relevant simulations (Peddle et al., 2020). Nevertheless, simulation remains a powerful instructional method that offers students unique opportunities for developing essential skills in a controlled environment (Medley & Horne, 2005; Leighton, 2013; Stroup, 2014).

Additionally, limited infrastructure and resources hinder the implementation of large-scale simulation programs, particularly in rural areas with limited technological resources. Despite the clear educational benefits of simulation-based learning, significant disparities exist among nursing programs globally (Alharbi & Alharbi, 2022; Salman, 2021). Institutions with greater resources can afford HFS, offering students advanced, realistic clinical training. In contrast, many programs, particularly in low-resource settings, rely on LFS due to its affordability but limited realism. This gap creates unequal learning opportunities, potentially impacting clinical readiness and competence among nursing graduates worldwide. Faculty and staff must also invest significant time and effort in planning and coordinating simulations, which can strain institutional capacity and affect the delivery of essential training (Jeffries et al., 2015).

Materials and methods

Study selection process

This meta-analysis was conducted in accordance with the Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. Researchers comprehensively searched multiple electronic databases, including PubMed, CINAHL, ERIC, ScienceDirect, and ProQuest. Relevant literature published between 2000 and 2025 was identified using key terms such as "simulation-based education," "high-fidelity simulation," "low-fidelity simulation," and "nursing students." Studies were included if they met the following inclusion criteria: (a) experimental or quasi-experimental design, such as randomized controlled trials (RCTS), cohort studies, or pre-post-test designs; (b) the study population comprised undergraduate or graduate nursing students; (c) use of either HFS- or LFS-based educational intervention; and (d) reported outcomes focusing on clinical and cognitive skills, self-efficacy, and decision-making abilities.

The following exclusion criteria were used: (a) simulation was not employed as an intervention, (b) quantitative outcomes related to psychomotor skills, cognitive outcomes or self-efficacy were not reported, or (c) qualitative research, case studies, or systematic reviews without original data that size effect cannot computed. Duplicate studies were removed following eligibility assessment.

Quality appraisal using the National Institute for Health and Care Excellence Quality Appraisal Checklist

The methodological rigor of the included studies was assessed using the National Institute for Health and Care Excellence (NICE) Quality Appraisal Checklist, a tool widely employed in health research to ensure the credibility and integrity of quantitative evidence. This checklist evaluates key methodological domains, including the study design, sample size, outcome measurement, and the appropriateness of statistical analyses (Zhao et al., 2024).

Each study was appraised based on several criteria. First, the study design was examined to determine whether it provided a clear framework for addressing the research question. Second, sampling procedures were assessed to ensure that sample sizes were adequate for detecting meaningful effects. Third, outcome measures were reviewed for clarity, validity, and relevance to simulation-based education, particularly regarding assessment outcomes. Fourth, data analysis techniques were evaluated for the use of proper statistical procedures. Finally, studies were scrutinized for control of potential confounding variables. Quality ratings are presented using a scale of one to five, where one indicates the lowest and five indicates the highest methodological quality.

Effect size computation

Effect size is a measure of how meaningful or strong a result is, showing the real-world impact of an intervention beyond just statistical significance. Effect sizes were derived from the mean and standard deviation (SD) values collected before and after the intervention. Researchers quantified the effects of simulation-based education on nursing students' psychomotor skills, cognitive outcomes, and self-efficacy using the analysis Standardized Mean Difference (SMD) method.

SMDs were calculated by comparing mean outcomes between simulation (intervention) and non-simulation (control) groups, allowing for standardized comparisons across studies with different outcome measures (Cuijpers et al., 2016). A positive SMD indicated that simulation-based education improved outcomes, whereas a negative SMD suggested minimal or no effect. Effect sizes were categorized into three domains: psychomotor skills (clinical execution), cognitive outcomes (critical thinking and decision-making), and self-efficacy (perceived competence in task performance).

Results

Characteristics of the selected studies

In total, 18 studies met the inclusion criteria and were incorporated into the meta-analysis. These studies involved over 3000 nursing students across various specialties, including general nursing practice, pediatric, and medical-surgical nursing (Fig. 3).

This meta-analysis incorporated studies that vastly differed in design and simulation methods within simulation-based nursing education. Most studies employed RCTs or quasi-experimental designs, which strengthened their overall methodological quality. These designs facilitated assessment of the impact of simulation-based learning on clinical skills, self-efficacy, and decision-making skills. The number of participants ranged considerably, from 102 participants (Shaban, 2021) to 4421 participants (Li et al., 2022). Illustration of the number of studies is shown in Fig. 4.

HFS was the most employed method, offering interactive and immersive experiences through real-world technology, including computerized patient avatars and advanced mannequins. Some studies included LFS either for comparison with HFS or to assess its impact on the learning outcomes, although it was less frequently employed. The inclusion of both HFS and LFS allowed the examination of how different simulation fidelities influenced the development of clinical competence.

The studies addressed various areas of nursing practice, including general nursing, such as foundational and non-specialized practice, pediatric nursing, and medical-surgical nursing, thereby broadening the understanding of simulation-based education across specialties. A detailed description of the selected studies is provided in Appendix A.

Quality appraisal using the NICE Quality Appraisal Checklist

Quality ratings are presented in Fig. 5, and Appendix B presents the quality ratings for each study included in the meta-analysis based on the NICE Quality Appraisal Checklist. Most studies received high ratings (4

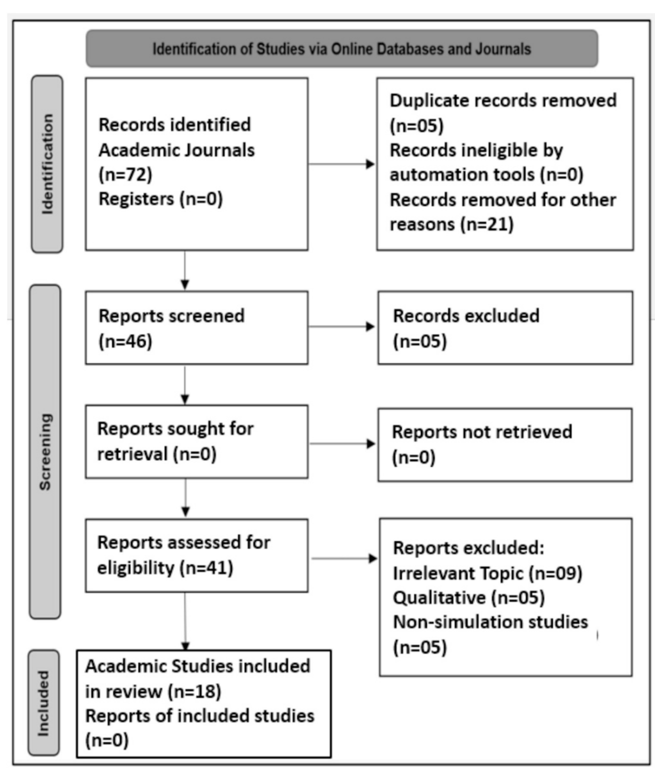

Fig. 3. PRISMA flow diagram.

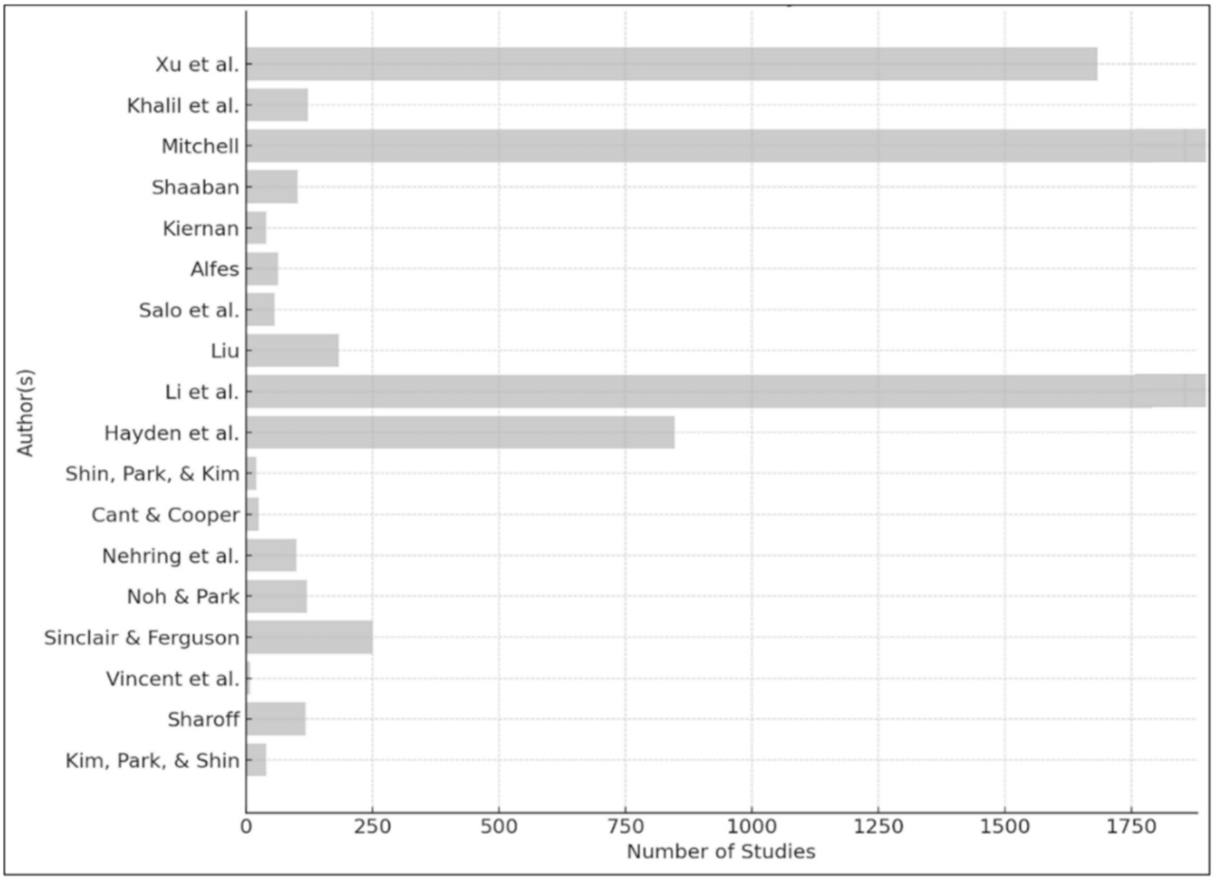

Fig. 4. Number of studies.

or 5), indicating strong methodological quality. However, some were rated lower due to small sample sizes or limited randomization.

Effect size computation and comparison between HFS and LFS

The raw data used for the effect size calculation for each domain are detailed in Table 1. All studies were performed separately, and a summary of each domain's effect size is presented in Fig. 6.

With a significant effect size of SMD = 0.86, HFS was confirmed to be instrumental in facilitating the improvement of students' core competencies, including psychomotor skills, cognitive outcomes, and self-efficacy. In comparison, the pooled effect size or combination of data from several studies demonstrates that the effect size of LFS was moderate at 0.56, indicating the potential of LFS and illustrates its shortcomings compared with HFS. Furthermore, psychomotor skills had the highest effect size (0.91), followed by self-efficacy, which was 0.88. and cognitive outcomes with effect size (0.72) Specifically, the inclusion of self-efficacy for pediatric nursing (SMD = 1.00) and psychomotor for medical-surgical nursing (SMD = 0.83) contributed to this overall large effect, suggesting that HFS is particularly beneficial in these highly specialized areas that require sophisticated patient care and complex patient management.

The pooled effect sizes for HFS and LFS simulations are shown in a forest plot, which displays results from multiple studies along with their effect sizes and confidence intervals (Fig. 7). A plot line in the middle shows no effect. The funnel plot (Fig. 8) spreads out evenly and symmetrically and suggests a low risk of publication bias. The meta-analysis table (Table 2) presents the computational breakdown of all effect sizes, including the SD and confidence intervals. The comparative and variance of pooled effect sizes by simulation type are presented visually in the bar chart (Fig. 9), and their proportional distribution is summarized in the pie chart (Fig. 10).

Overall, HFS was found to be more effective across all measured domains, particularly in enhancing psychomotor skills, cognitive outcomes and self-efficacy. According to Shin et al. (2015) and Vincent et al. (2015), the realistic scenarios and advanced technologies in HFS foster deeper engagement in clinical reasoning and higher-order thinking, better preparing students for real-world practice. While LFS supports the acquisition of basic clinical skills, its effect on developing psychomotor competence is comparatively limited.

Further analysis revealed that HFS significantly improved nursing students' decision-making, cognitive abilities, and psychomotor performance. The most notable gains were observed in students specializing in pediatric and medical-surgical nursing. Pediatric nursing students demonstrated the greatest improvements in decision-making and self-efficacy, likely due to the emotionally complex and high-responsibility nature of pediatric care (McCaughey & Traynor, 2010; Park & Yu, 2018). Medical-surgical nursing students also exhibited large positive effect sizes, though these were slightly less pronounced than those seen in the pediatric cohort.

Discussion

The key finding of this meta-analysis is the significant improvement in psychomotor skills, cognitive outcomes, and self-efficacy among nursing students exposed to HFS compared with those exposed to LFS. The overall pooled effect size for HFS was 0.86, indicating a strong positive impact on student outcomes, whereas LFS yielded a moderate effect size of 0.56. While LFS retains educational value, it lacks the depth, realism, and learner engagement inherent in HFS.

Evidence from the literature supports the superiority of HFS in promoting clinical readiness through realistic and interactive learning

Fig. 5. Quality rating of selected studies using NICE.

Table 1
Effect size for pre and post simulation computation.

No	Domain	Pre-Simulation Mean (SD)	Post-Simulation Mean (SD)	Effect Size (SMD)
1	High Fidelity Simulation	5.2 (1.2)	7.3 (1.0)	0.86
2	Low Fidelity Simulation	3.9 (0.8)	5.0 (0.7)	0.56
3	Pediatrics (Self-Efficacy)	2.8 (1.0)	4.0 (0.9)	1.00
4	Medical Surgical (Psychomotor)	4.5 (1.1)	6.0 (1.0)	0.83

environments. HFS immerses students in complex, high-pressure scenarios that closely mimic real clinical situations. These simulations often employ life-like mannequins and VR technologies to enable safe practice in essential nursing competencies such as patient assessment, clinical judgment, and procedural execution (Vincent et al., 2015). Such technology enhances knowledge retention by enabling students to experience realistic clinical challenges without risking patient safety.

A notable advantage of HFS is its ability to strengthen clinical decision-making skills. In practice, nurses often make rapid decisions based on limited information and time-sensitive priorities. HFS supports learners through guided problem-solving and decision-making algorithms, building confidence and the ability to make sound judgments under pressure. Students trained with HFS perform more competently in clinical evaluations, particularly in high-stakes environments requiring swift, accurate decisions (McCaughey & Traynor, 2010; Shin et al., 2015).

These findings are especially prominent in pediatric nursing, where the pooled effect size reached 0.82, underscoring the critical role of simulation in preparing students for emotionally and technically demanding care (Fig. 11). Pediatric nursing requires both procedural skills and emotional sensitivity in interactions with children and their families. HFS fosters the development of these dual competencies by allowing students to rehearse complex scenarios, such as pediatric emergencies or medication administration, in a safe and controlled setting (Park & Yu, 2018).

Medical-surgical nursing students also benefited from simulation-based education, although with a slightly lower pooled effect size of 0.65. While statistically significant, this lower effect size may reflect the more routine, less emotionally intense nature of many medical-surgical tasks, which often include medication administration, monitoring vital signs, and wound care. Nevertheless, simulation remains essential in this field for reinforcing patient safety, procedural precision, and high-level clinical judgment, all of which are vital in acute and life-threatening situations (Nehring & Lashley, 2009).

Comparison with previous research

Our findings align with prior studies highlighting the effectiveness of HFS in developing psychomotor skills and clinical judgment. While pediatric nursing exhibited the highest effect size, improvements were also seen across other specialties, suggesting a broader benefit. The results reinforce existing literature that simulation enhances critical thinking and emotional competence, particularly in high-stakes disciplines. Furthermore, the study highlights the need for specialty-specific simulation programs to maximize educational outcomes (Kim et al., 2016; Vincent et al., 2015).

Limitations

Despite its strengths, this meta-analysis has limitations, including variability in the study designs, sample sizes, outcome measures, and simulation protocols. These inconsistencies contribute to heterogeneity

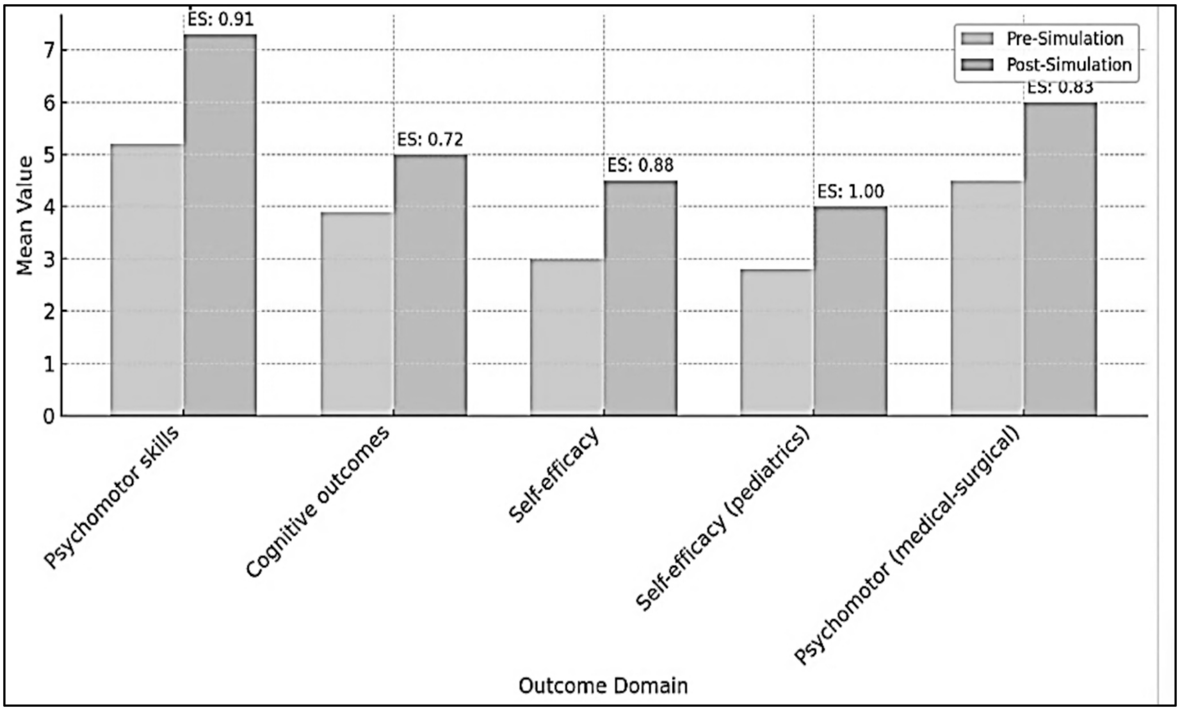

Fig. 6. Effect Size Computation on Pre and Post Simulation.

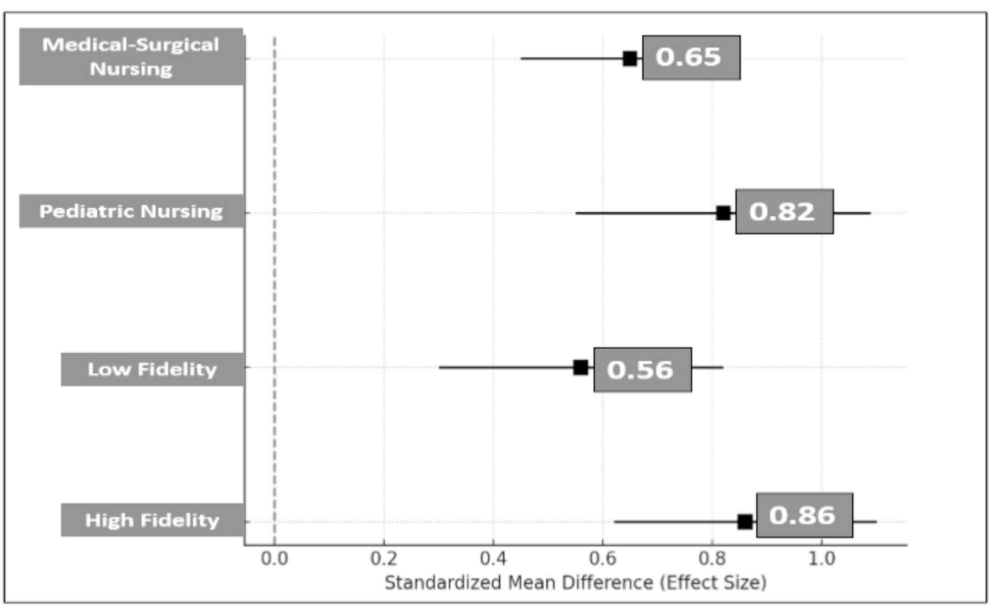

Fig. 7. Forest plot.

and may affect generalizability. Additionally, the absence of standardized guidelines for simulation delivery complicates the interpretation of specific impact factors. Future research should aim for methodological consistency, larger sample sizes, and long-term evaluations of simulation outcomes (Shin et al., 2015).

Implications for nursing education

Our findings have direct implications for nursing curricula. Integrating HFS into educational programs enables students to engage in complex clinical scenarios that foster technical skills and cognitive intelligence, especially in specialties like pediatric and medical-surgical nursing. Programs should explore optimal frequency, duration, and intensity of simulation-based training to support competency-driven learning outcomes. Establishing standardized simulation frameworks may better prepare students for clinical realities and improve educational quality (McCaughey & Traynor, 2010; Park & Yu, 2018).

Conclusions

This meta-analysis affirms the value of simulation-based education particularly HFS in enhancing nursing students' readiness for clinical practice. HFS significantly improved psychomotor skills, cognitive outcomes, and self-efficacy by immersing students in realistic, risk-free

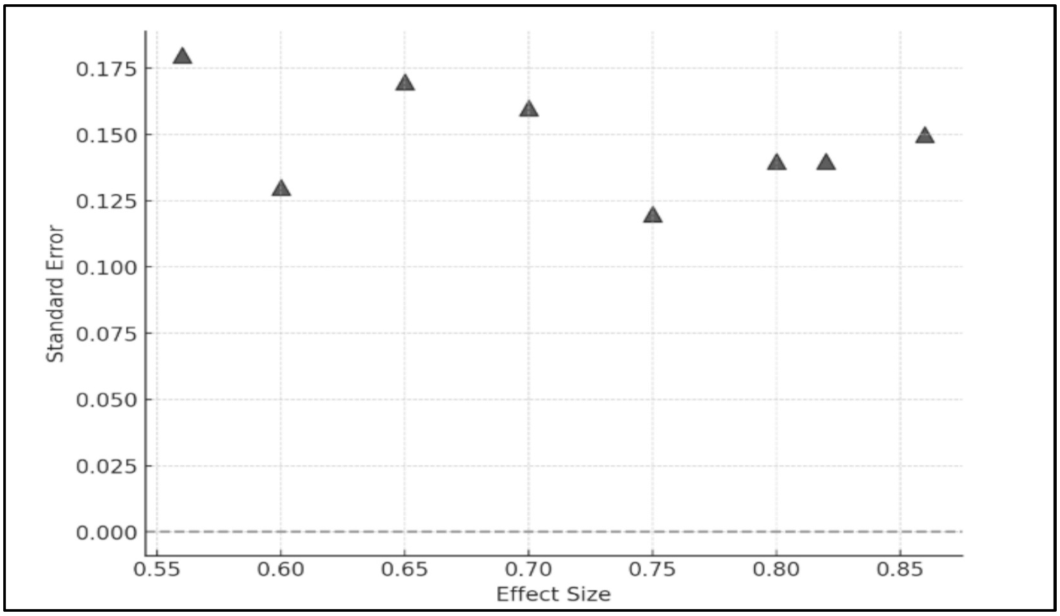

Fig. 8. Funnel plot.

Table 2
Results of meta-analysis.

Simulation type	Pooled effect size (SMD)	Standard deviation (SD)	Confidence interval (95 %)
High-fidelity Simulation	0.86	0.12	0.62, 1.10
Low-fidelity Simulation	0.56	0.18	0.30, 0.82
Pediatric Nursing	0.82	0.15	0.55, 1.09
Medical-Surgical Nursing	0.65	0.20	0.45, 0.85

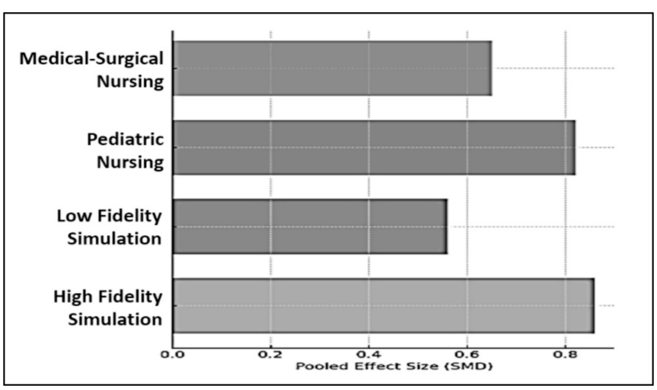

Fig. 9. Pooled effect size.

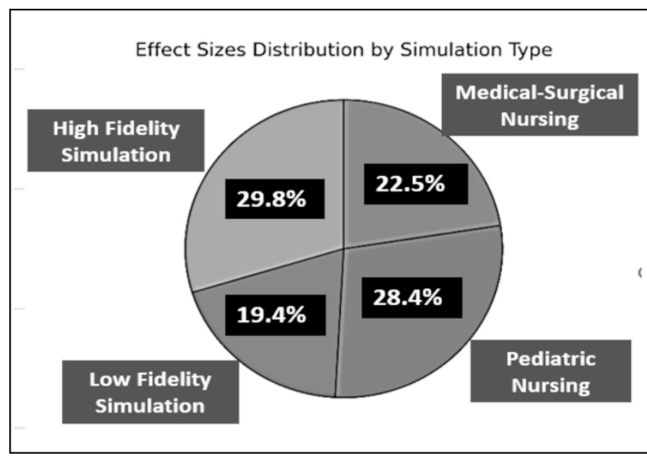

Fig. 10. Effect size distribution by simulation type.

environments. The strongest impact was observed in pediatric nursing, where complex decision-making and empathy are critical. While LFS provides moderate benefits, HFS offers deeper engagement and superior learning outcomes. To enhance nursing education, simulation strategies should be tailored to specialty-specific needs and implemented consistently. Continued innovation and refinement of simulation methods may enhance clinical readiness and ultimately improve patient care and safety.

CRediT authorship contribution statement

William D. Taala: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fahad M. Althobaiti:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Rino S. De Sagun:** Writing – original draft, Methodology, Conceptualization. **Rock P. Cordero:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Jake Canapi:** Writing – original draft, Formal analysis, Data curation, Conceptualization. **Jon Jon Martinez:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Ethical statement

This meta-analysis was conducted using data extracted from previously published studies. As no new data were collected directly from human participants, ethical approval and informed consent were not required.

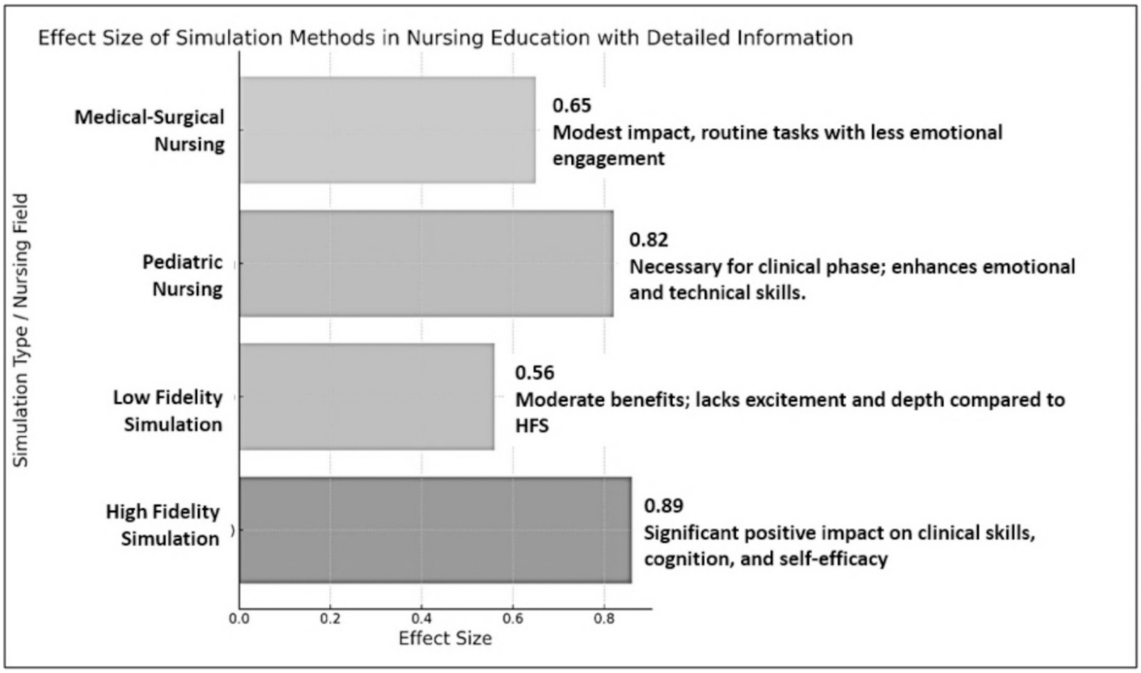

Fig. 11. Effect size simulation methods in nursing training programs.

Declaration of Generative AI and AI-assisted technologies in the writing process

No generative AI tools were used in the writing, editing, or data analysis of this manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The author sincerely thanks the Dean of Postgraduate Studies and Scientific Research for the invaluable support and encouragement that contributed to the successful completion of this research.

Appendix A. Key characteristics of selected studies

S No	Author(s)	Year	Study design	Sample size	Simulation type
1	Kim, Park, & Shin	2016	Meta-analysis	40 studies	HFS, LFS
2	Shin, Park, & Kim	2015	Meta-analysis	20 studies	HFS, LFS
3	Vincent et al.	2015	Review & Meta-analysis	8 studies	HFS
4	Sinclair & Ferguson	2009	Quasi-experimental	250	MFS
5	Noh & Park	2022	Quasi-experimental	120	SBAR-integrated simulation
6	Nehring et al.	2009	Randomized Trial	100	HFS
7	Cant & Cooper	2016	Systematic Review	25 studies	HFS, LFS
8	Sharoff	2022	Quasi-experimental	118 students (99 pre-licensure, 19 accelerated	vSim
9	Hayden et al.	2014	Longitudinal, Randomized, Controlled Trial	847	HFS
10	Li et al.	2022	Meta-analysis	4541	HFS
11	Liu	2025	RCT	184	vSim
12	Salo et al.	2025	Qualitative Case Study	56	vSim
13	Alfes	2011	Quasi-experimental	63	HFS
14	Kiernan	2018	Quasi-experimental	40	HFS
15	Shaaban	2021	Comparative Research Design	102	HFS
16	Mitchell	2023	Systematic Review	1790	HFS, LFS
17	Khalil et al.	2023	Randomized Experimental	123	Scenario simulation
18	Xu et al.	2021	Systematic Review & Meta-analysis	1683	Scenario simulation

Appendix B. NICE Quality Appraisal Checklist

S No	Author(s)	Sample size	Study design	Quality Rating (1–5)	Comments
1	Kim, Park, & Shin	40	Meta-analysis	4	Strong design, control group, comprehensive outcome measures
2	Sharoff	118	Quasi-experimental	4	Well-designed study, good outcome measures
3	Vincent et al.	8	Review & Meta-analysis	3	Small sample, varied outcome measures
4	Sinclair & Ferguson	250	Quasi-experimental	3	Limited sample size, good outcome measures
5	Noh & Park	120	Quasi-experimental	4	Well-designed study, good outcome measures
6	Nehring et al.	100	Randomized Trial	3	Randomization, Vague outcome measures
7	Cant & Cooper	25	Systematic Review	3	Small study sample, good design but limited data
8	Shin, Park, & Kim	20	Meta-analysis	5	High-quality meta-analysis with standardized outcomes
9	Hayden et al.	847	Longitudinal, Randomized, Controlled Trial	4	Strong sampling, valid outcome measures
10	Li et al.	4541	Meta-analysis	5	Rigorous analysis, strong statistical methods
11	Liu	184	RCT	4	Well-conducted RCT with large sample size
12	Salo et al.	56	Qualitative Case Study	4	Strong methodology, high-quality review
13	Alfes	63	Quasi-experimental	4	High-quality analysis, but small number of studies included
14	Kiernan	40	Quasi-experimental	3	Generalization in outcomes
15	Shaaban	102	Comparative Research Design	5	Rigorous analysis, strong statistical methods
16	Mitchell	1790	Systematic Review	4	High-quality design, appropriate outcome measures
17	Khalil et al.	123	Randomized Experimental	3	Strong design but small data
18	Xu et al.	1683	Systematic Review & Meta-analysis	4	Clear and detailed outcomes, strong design

Data availability

The data used in this meta-analysis were extracted from publicly available published articles, which are cited throughout the manuscript.

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